IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF MASSACHUSETTS

BRAUN GmbH, Plaintiff, v. RAYOVAC CORPORATION, Defendant.	Civil Action No. 03-CV-12428-WGY

REPORT OF SAMIR NAYFEH

Dated: May 23, 2005

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I. INTRODUCTION

I am an Assistant Professor of Mechanical Engineering at the Massachusetts Institute of Technology in Cambridge, Massachusetts. A copy of my curriculum vitae is attached to this Report at Exhibit A.

I was retained by Braun GmbH ("Braun") to examine cleaning devices for electric shavers, which I understand to be sold by Rayovac Corporation ("Rayovac"), and to opine as to whether these devices infringe two patents -- U.S. Patent No. 5,711,328 (the "'328 Patent") and U.S. Patent No. 5,649,556 (the "'556 Patent"), which I understand to be owned by Braun. I am being compensated at an hourly rate for the work that I perform in this matter. My hourly rate is $300. This compensation is unaffected by the outcome of this matter.

In order to arrive at my opinion, I have reviewed the '328 Patent and the '556 Patent. I have also reviewed the patent prosecution histories for each of these patents.

In addition, I have examined three Remington products – two "Titanium Smart System" electric shaving systems: a men's rotary system with product designation R-9500 (the "R-9500 cleaning system") and a men's foil system with product designation MS-5500 (the "MS-5500 cleaning system");[1] and one "Smooth & Silky Titanium System", which is a women's foil system with product designation WDF-7000CS (the "WDF-7000CS cleaning system"). Each of these Rayovac products includes an electric shaver and a cleaning system.

I have also reviewed the parties' *Markman* briefs, and accompanying exhibits, which I understand to have been submitted with the Court in this matter. Finally, I have reviewed the transcript from the March 15, 2005 *Markman* hearing.

II. OPINION SUMMARY

In my opinion, each of the three Rayovac cleaning systems, which I have examined, infringes claims 11, 12, 14, and 18 of the '328 Patent. As discussed in more detail below, each of the claim elements of each of these claims is found in each of the three Rayovac cleaning systems.

In my opinion, each of the three Rayovac cleaning systems, which I have examined, infringes claims 1, 6, and 18 of the '556 Patent. As discussed in more detail below, each

[1] I understand that Rayovac sells another men's foil shaver cleaning system with product designation MS-5700. I further understand that this MS-5700 cleaning system differs from the MS-5500 cleaning system only with respect to certain details of the electric shaver, which do not affect the cleaning operation and that the MS-5700 cleaning system is identical in all material respects to the MS-5500 cleaning system. Therefore, my opinion with regard to the MS-5700 cleaning system is the same as my opinion with regard to the MS-5500 cleaning system.

of the claim elements of each of these claims is found in each of the three Rayovac cleaning systems.

III. COMPARISON OF CLAIMS AND RAYOVAC PRODUCTS

In the following charts, I compare the claims of the '328 Patent and the '556 Patent to the Rayovac cleaning systems. Each of the three Rayovac cleaning systems, which I have examined, operates in substantially the same manner. In each, an electric shaver is inserted into a housing to be cleaned, dried, charged, and stored. During the cleaning operation, cleaning fluid is fed from a container to a structure that supports or receives the shaving head of the electric shaver.

In the attached photographs of these cleaning systems, corresponding components of the R-9500, MS-5500, and WDF-7000CS cleaning systems are given the same numbers, and the descriptions and analysis in the following apply equally to each of the three systems unless noted. Figures 1a-1d are photographs of the R-9500 cleaning system and are attached to this report as Exhibit B; Figures 2a-2c are photographs of the MS-5500 cleaning system and are attached to this report as Exhibit C; Figures 3a-3c are photographs of the WDF-7000CS cleaning system and are attached to this report as Exhibit D.

THE '328 PATENT

Claim 11

Claim 11 Of The '328 Patent	The Court's Construction	The Remington Shaving System
A cleaning device comprising:		Each Rayovac cleaning system includes an electric shaver 1 and a cleaning device contained in a housing 2 and including a container 5, as shown in Figures 1a, 2a, and 3a. The electric shaver 1 is inserted into the housing 2 to be cleaned, dried, charged, and stored.
a cradle structure adapted to receive a shaving head of a shaving apparatus,	a structure adapted to support or receive a shaving head of a shaving apparatus and able	Referring to Figures 1a, 2a-c, and 3a-c, the cleaning device of each system includes manifold 3a with ports 3b and supporting structures 3c.[2] When the shaving head 4 of the shaver 1 is

[2] Only a subset of the ports 3b and supporting surfaces 3c are labeled in each photograph. The R-9500 cleaning system has three ports 3b and several protruding supporting surfaces 3c. The MS-5500 cleaning system has four ports 3b and several supporting surfaces 3c on a spring-supported structure. The WDF-7000CS cleaning system has two ports 3b and several supporting surfaces 3c on a spring-supported structure.

Claim 11 Of The '328 Patent	The Court's Construction	The Remington Shaving System
	to receive or retain fluid or both	inserted into the cleaning system, it bears against the ports 3b and the surfaces of supporting structures 3c, and is thereby supported in place. The manifold 3a, ports 3b, and supporting structures 3c together constitute the cradle structure.
a cleaning fluid container,	a container for holding cleaning fluid	Referring to Figures 1b, 2b, and 3b, a container 5 holds cleaning fluid.
a feed device for feeding cleaning fluid to said cradle structure,	a mechanism that feeds cleaning fluid from the cleaning fluid container to the cradle structure	Referring to Figures 1c, 2c, and 3c, a pump 6 and conduit 7 feed fluid to the manifold 3a and ports 3b of the cradle structure during the cleaning operation.
said cradle structure being arranged above a fluid level of the cleaning fluid in said cleaning fluid container during the feeding of said cleaning fluid to said cradle structure, and	During the feeding of said cleaning fluid to said cradle structure, the cradle structure is above the fluid level of the fluid in the fluid container.	The cradle structure 3a, 3b, and 3c is located above the cleaning fluid level in the container 5 during the feeding of cleaning fluid to the cradle structure.
a drying device.	a drying device.	Referring to Figures 1c, 2c, and 3c, the cleaning device of each system includes a rotor 8 in an impeller casing 9 configured to blow air through an opening in the impeller casing 9 to the shaving head 4. This airflow serves to dry the shaving head 4.

Claim 12

Claim 12 of the '328 Patent adds one limitation to claim 11: that the drying device comprises an impeller.

Claim 12 Of The '328 Patent	The Court's Construction	The Remington Shaving Systems
A device as claimed in claim 11, wherein the drying device comprises an impeller.	The device comprises an impeller, which is a rotating device or member of a turbine, blower, fan, axial or centrifugal pump.	Referring to Figures 1c, 2c, and 3c, each cleaning system includes a rotor 8, which moves inside an impeller casing 9 to impart motion to air in order to dry the electric shaver. The rotor 8 is an impeller.

Claim 14

Claim 14 of the '328 Patent is identical to claim 11 except that claim 14 includes the limitation that the cradle structure 3a, 3b and 3c be permanently open to atmosphere and does not require that the cleaning system include a drying device. For each Rayovac cleaning system, the cradle structure 3a, 3b and 3c is permanently open to the atmosphere. This enables the shaver to be inserted in the cradle structure without any effort and to be removed without the need to utilize any parts closing the cradle structure. This arrangement eliminates the need to provide an elaborate seal around the cradle structure. In all other respects, claim 14 is identical to claim 11, and therefore my analysis of the remaining elements of claim 14 follows the analysis for claim 11 above.

Claim 14 Of The '328 Patent	The Court's Construction	The Remington Shaving Systems
A cleaning device comprising		Each Rayovac cleaning system includes an electric shaver 1 and a cleaning device contained in a housing 2 and including a container 5, as shown in Figures 1a, 2a, and 3a. The electric shaver 1 is inserted into the housing 2 to be cleaned, dried, charged, and stored.
a cradle structure adapted to receive a shaving head of a shaving apparatus, said cradle structure being permanently open to atmosphere,	a structure adapted to support or receive a shaving head of a shaving apparatus and able to receive or retain fluid or both, permanently open towards the open	Referring to Figures 1a, 2a-c, and 3a-c, the cleaning device of each system includes manifold 3a with ports 3b and supporting structures 3c. When the shaving head 4 of the shaver 1 is inserted into the cleaning system, it bears against the ports 3b and the surfaces of supporting structures 3c, and is thereby supported in place. The manifold 3a, ports 3b, and supporting structures 3c

Claim 14 Of The '328 Patent	The Court's Construction	The Remington Shaving Systems
	air.	together constitute the cradle structure. The cradle structure 3a, 3b, and 3c is permanently open to the atmosphere. As a result, the shaver 1 is easily insertable in the cradle structure 3a, 3b, and 3c and removable therefrom. No elaborate seal is provided.
a cleaning fluid container,	a container for holding cleaning fluid	Referring to Figures 1b, 2b, and 3b, a container 5 holds cleaning fluid.
a feed device for feeding cleaning fluid to said cradle structure,	a mechanism that feeds cleaning fluid from the cleaning fluid container to the cradle structure	Referring to Figures 1c, 2c, and 3c, a pump 6 and conduit 7 feed fluid to the manifold 3a and ports 3b of the cradle structure during the cleaning operation.
said cradle structure being arranged above a fluid level of the cleaning fluid in said cleaning fluid container during the feeding of said cleaning fluid to said cradle structure.	During the feeding of said cleaning fluid to said cradle structure, the cradle structure is above the fluid level of the fluid in the fluid container.	The cradle structure 3a, 3b, and 3c is located above the cleaning fluid level in the container 5 during the feeding of cleaning fluid to the cradle structure.

Claim 18

Claim 18 of the '328 Patent is identical to claim 11 except that claim 18 includes the limitation that the cleaning system include a bracket for insertion of the shaver, and does not require that it include a dryer. In all other respects, claim 18 is identical to claim 11, and therefore my analysis of the remaining elements of claim 18 follows the analysis for claim 11 above.

Claim 18 Of The '328 Patent	The Court's Construction	The Remington Cleaning Systems
A cleaning device comprising		Each Rayovac cleaning system includes an electric shaver 1 and a cleaning device contained in a housing 2 and including a container 5, as shown in Figures 1a, 2a, and 3a. The electric shaver 1 is inserted into the housing 2 to be cleaned, dried, charged, and stored.

Claim 18 Of The '328 Patent	The Court's Construction	The Remington Cleaning Systems
a cradle structure adapted to receive a shaving head of a shaving apparatus,	a structure adapted to support or receive a shaving head of a shaving apparatus and able to receive or retain fluid or both	Referring to Figures 1a, 2a-c, and 3a-c, the cleaning device of each system includes manifold 3a with ports 3b and supporting structures 3c. When the shaving head 4 of the shaver 1 is inserted into the cleaning system, it bears against the ports 3b and the surfaces of supporting structures 3c, and is thereby supported in place. The manifold 3a, ports 3b, and supporting structures 3c together constitute the cradle structure.
a cleaning fluid container,	a container for holding cleaning fluid	Referring to Figures 1b, 2b, and 3b, a container 5 holds cleaning fluid.
a feed device for feeding cleaning fluid to said cradle structure,	a mechanism that feeds cleaning fluid from the cleaning fluid container to the cradle structure	Referring to Figures 1c, 2c, and 3c, a pump 6 and conduit 7 feed fluid to the manifold 3a and ports 3b of the cradle structure during the cleaning operation.
said cradle structure being arranged above a fluid level of the cleaning fluid in said cleaning fluid container during the feeding of said cleaning fluid to said cradle structure, and	During the feeding of said cleaning fluid to said cradle structure, the cradle structure is above the fluid level of the fluid in the fluid container.	The cradle structure 3a, 3b, and 3c is located above the cleaning fluid level in the container 5 during the feeding of cleaning fluid to the cradle structure.
a bracket for insertion of the shaving apparatus therein.	a bracket or projecting support	Referring to Figures 1a, 2a, and 3a, the Rayovac cleaning systems include a vertically extending structure 10 and an overhanging projection 11 into which the electric shaver 1 is inserted. Extending structure 10 together with overhanging projection 11 constitute a bracket or projecting support.

THE '556 PATENT

Claim 1

Claim 1 Of The '556 Patent	The Court's Construction	The Remington Cleaning Systems
A cleaning device for cleaning a shaving head of a dry shaving apparatus, said cleaning device comprising		Referring to Figures 1a, 2a, and 3a, the Rayovac cleaning systems include an electric shaver 1 and a cleaning device contained in a housing 2 and including container 5. The electric shaver 1 is inserted into the housing 2 to be cleaned, dried, charged, and stored.
a cradle structure adapted to receive therein the shaving head;	a structure adapted to support or receive a shaving head of a shaving apparatus and able to receive or retain fluid or both,	Referring to Figures 1a, 2a-c, and 3a-c, the cleaning device of each system includes manifold 3a with ports 3b and supporting structures 3c. When the shaving head 4 of the shaver 1 is inserted into the cleaning system, it bears against the ports 3b and the surfaces of supporting structures 3c, and is thereby supported in place. The manifold 3a, ports 3b, and supporting structures 3c together constitute the cradle structure.
a cleaning fluid container separate from the cradle structure for holding a cleaning fluid;	a separate cleaning fluid container that is a removable cartridge which holds cleaning fluid,	Referring to Figures 1b, 2b, and 3b, the container 5 holds cleaning fluid. The container 5 can be easily removed from the housing 2 and refilled with cleaning fluid when needed. The container 5 is distinct or separate from the cradle structure 3a, 3b, and 3c.
a filter; and	a filter,	Referring to Figure 1d, the cleaning system includes a filter 12 with an inlet port at its top 13 and permeable mesh walls 14.
a fluid feed mechanism which feeds the cleaning fluid after it passes through the filter to the cradle structure during cleaning,	a mechanism that feeds cleaning fluid from the cleaning fluid container to the cradle structure after it passes through the filter (from the pump to	Cleaning fluid passes through the filter 12 to enter the container 5. Referring to Figures 1c, 2c, and 3c, a pump 6 draws fluid from the container 5 after it passes through the filter 12, pumping it via the conduit 7 to the cradle structure manifold 3a and ports 3b during the cleaning operation. The pump 6 is therefore a fluid

Claim 1 Of The '556 Patent	The Court's Construction	The Remington Cleaning Systems
	the filter and then to the cradle).[3]	feed mechanism that feeds the fluid after it passes through the filter 12 to the cradle structure.
said container and filter being separable from the cradle structure as a unit.	The container and filter are integrally formed or assembled as a unit, such unit being removable from the cleaning device.	Referring to Figures 1b, 2b, and 3b, the filter 12 and container 5 are assembled as a unit in that filter 12 is assembled to the container 5. When the container 5 is removed from the housing 2, both the filter 12 and container 5 are separated from the cleaning device together as a unit.

Claim 6

Claim 6 of the '556 Patent is identical to claim 1 except that it includes the further limitation that the container include ports through which cleaning fluid pass in and out of the cleaning fluid container. The Rayovac cleaning systems each includes an inlet port 14 at the top of the filter 13 and an outlet port 15.

Claim 6 Of The '556 Patent	The Court's Construction	The Remington Cleaning Systems
A cleaning device as claimed in claim 1, wherein the cleaning fluid container contains ports through which cleaning fluid passes in and out of the cleaning fluid container.	The cleaning fluid container includes inlet and outlet ports through which cleaning fluid passes into and out of the cleaning fluid container.	Referring to Figure 1d, the cleaning fluid enters the container 5 through an inlet port 13 and leaves through an outlet port 15.

Claim 18

Claim 18 of the '556 Patent is identical to claim 1 except that it includes the further limitation that the cradle structure be open to the atmosphere and supplied with cleaning fluid from cleaning fluid container by means of the fluid feed mechanism. In the Rayovac cleaning systems, the cradle structure 3a, 3b and 3c is permanently open to the atmosphere. This enables the shaver to be inserted in the cradle structure without any effort and to be removed without the need to utilize any parts closing the cradle structure. This arrangement eliminates the need to provide an elaborate seal around the cradle

[3] Consistent with the claim language, I interpret this to mean that the claim requires that the fluid be fed to the cradle structure after the cleaning fluid passes through the filter. The particular order of fluid flow is not limited by the claim.

structure. The Rayovac cleaning systems each includes a pump 6 and conduits 7 and 8 feed fluid to the cradle structure 3a, 3b and 3c during the cleaning operation.

Claim 18 Of The '556 Patent	The Court's Construction	The Remington Cleaning Systems
A cleaning device as claimed in claim 1, wherein the cradle structure is open towards atmosphere and is supplied with cleaning fluid from the cleaning fluid container by means of the fluid feed mechanism.	The cradle structure is open towards the atmosphere. The cradle structure is supplied with cleaning fluid from the cleaning fluid container by the fluid feed mechanism.	Referring to Figures 1a, 2a, and 3a, the cradle structure 3a, 3b and 3c in each Rayovac cleaning system is permanently open to the atmosphere. As a result, the shaver 1 is easily insertable in the cradle structure 3a, 3b, and 3c and removable therefrom. No elaborate seal is provided. The Rayovac cleaning systems each includes a pump 6 and conduits 7 feed fluid to the cradle structure 3a, 3b and 3c during the cleaning operation.

IV. CONCLUSION

The three Rayovac cleaning systems infringe claims 11, 12, 14, and 18 of the '328 Patent and claims 1, 6, and 18 of the '556 Patent.

The opinions expressed in this report are based upon material made available to me in sufficient time for my review as of the date of this report. Should additional information be made available to me, I may supplement my opinions as expressed herein.

5/23/05

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May 23, 2005

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Principal Fields of Interest

- machine design, structural dynamics, composite materials, precision engineering, motion control

Employment History

- Assistant Professor, Department of Mechanical Engineering, Massachusetts Institute of Technology (MIT), July 98–July 05.
- Associate Professor, Department of Mechanical Engineering, MIT, effective July 05.

Education

- BS, Engineering Science and Mechanics, Virginia Tech, 1991.
- MS, Engineering Mechanics, Virginia Tech, 1993.
- PhD, Mechanical Engineering, MIT, 1998.

Awards Received

- Best Paper, Structural Dynamics Committee of the International Gas Turbine Institute, 2002.
- Gas Turbine Award for the Most Outstanding Technical Paper in *ASME Journal of Turbomachinery*, 2002.

Memberships and Professional Service

- Organizing Committee, *Symposium on Damping and Isolation*, SPIE Smart Structures and Materials Conference, Spring 2002–present.
- NSF Review Panel for Design, Manufacturing, and Industrial Innovation, Spring 2003.
- Member of: American Society for Precision Engineering, American Society of Mechanical Engineers, and American Insititute of Aeronautics and Astronautics.

Major Research Projects

1. Ford Motor Company	"Advanced Tool Holding," development of low-runout collets with improved damping for gun drills and slender milling tools, 1999–2000.	$160,000
2. Pro Cut International	"Automatic Cutting Head for an On-Car Brake Lathe," design of a compact numerically controlled cutting head for machines which perform insitu refacing automotive brakes, 2000–2001.	$67,000
3. Silicon Valley Group	"Dynamic Modeling of a Photolithography System," development of modeling techniques suitable for complicated precision machines, damping techniques suitable for ultra-precision structures, 2000–2001.	$215,000
4. Caterpillar	"Development of Pin Joints with Improved Galling Resistance," analytical and experimental study of factors affecting galling failures in heavily-loaded pin-bushing pairs, development of improved bushings using tailored compliance, 2001–2002.	$245,000
5. Bally Ribbon Mills	"Development of a Bias Weaving System," design and development of a full-scale machine that makes 3D woven structures with multi-axis strength and stiffness by interweaving yarns that run at angles with yarns that run at 0 and 90 degrees, 2001–2004.	$1,130,000
6. Laser Interferometer Gravitational-Wave Observatory	"Active and Passive Vibration Isolation," study and development of feedforward and feedback techniques, integral passive damping, and measurement-based decoupling techniques for the MIT/Caltech laser interferometer gravitational-wave observatory, 2002–2004.	$125,000
7. Ford Motor Company	"Integral Damping of Vehicle Propeller Shaft," study of the dynamics of vehicle drive shafts and development of damping approaches for vehicle noise reduction, 2005–2006.	$267,000
8. Deshpande Center for Technological Innovation	"Short-Warp Weaving," development of a modular weaving process and machine for reduction of setup costs and lead time to enable responsive, short-run production, 2005–2006.	$50,000

Teaching Experience

- "Introduction to Design and Manufacture," lab instructor. This is an introductory course on mechanical design, with an emphasis on individual design projects culminating in a contest.
- "Elements of Mechanical Design," lecturer, lab instructor, and project mentor. This is an undergraduate course that combines lectures, homeworks, and exams on the fundamentals of machine design with group "design-and-build" projects done for an external client.
- "Systems Modeling and Dynamics I," lecturer, recitation and lab instructor. This undergraduate course teaches the fundamentals of system modeling, linear-system dynamics, and feedback control.
- "Systems Modeling and Dynamics II," recitation and lab instructor. This undergraduate course focuses on the dynamics and control of mechanical systems.
- "Design of Motion Systems," lecturer. I developed this graduate course to teach the fundamentals of machine design for dynamic performance.

Papers in Refereed Journals

1. Nayfeh, S. A. and Nayfeh, A. H., "Nonlinear Interactions Between Two Widely Spaced Modes—External Excitation," *International Journal of Bifurcation and Chaos* 3, No. 2, pp. 417–427, 1993.
2. Nayfeh, S. A. and Nayfeh, A. H., 1994, "Energy Transfer from High- to Low-Frequency Modes in a Flexible Structure," *Journal of Vibration and Acoustics* 116, No. 2, pp. 203–207, 1994.
3. Nayfeh, A. H. and Nayfeh, S. A., "On Nonlinear Modes of Continuous Systems," *Journal of Vibration and Acoustics* 116, No. 1, pp. 129–136, 1994.
4. Nayfeh, A. H. and Nayfeh, S. A., "Nonlinear Normal Modes of a Continuous System with Quadratic Nonlinearities," *Journal of Vibration and Acoustics* 117, No. 2, pp. 199–205, 1994.
5. Nayfeh, A. H., Chin, C., and Nayfeh, S. A., "Nonlinear Normal Modes of a Cantilever Beam," *Journal of Vibration and Acoustics* 117, No. 4, pp. 477–481, 1995.
6. Pakdemirli, M., Nayfeh, S. A., and Nayfeh, A. H., "Analysis of One-to-One Autoparametric Resonances in Cables—Discretization vs. Direct Treatment," *Nonlinear Dynamics* 8, pp. 65–83, 1995.

7. Nayfeh, S. A., Nayfeh, A. H., and Mook, D. T., "Nonlinear Response of a Taut String to Parametric and External Excitation," *Journal of Vibration and Control* 1, pp. 307–334, 1995.

8. Nayfeh, A. H., Chin, C., and Nayfeh, S. A., "On Nonlinear Normal Modes of Systems with Internal Resonance," *Journal of Vibration and Acoustics* 118, pp. 340–345, 1996.

9. Al–Nahwi, A. A., Pauduano, J. D., and Nayfeh, S. A., "Aerodynamic-Rotordynamic Interaction in Axial Compression Systems—Part I: Modeling and Analysis of Fluid-Induced Forces," *ASME Journal of Turbomachinery* 125, pp. 405–415, 2003.

10. Al–Nahwi, A. A., Pauduano, J. D., and Nayfeh, S. A., "Aerodynamic-Rotordynamic Interaction in Axial Compression Systems—Part II: Impact on Overall System Stability," *ASME Journal of Turbomachinery* 125, pp. 416–424, 2003.

11. Zuo, L. and Nayfeh, S. A., "Low-Order Continuous-Time Filters for Approximation of the ISO 2631 Human Vibration Sensitivity Curves," *Journal of Sound and Vibration* 265, pp. 459–465, 2003.

12. Zuo, L. and Nayfeh, S. A., "Structured H2 Optimization of Vehicle Suspensions Based on Multi-Wheel Models," *Vehicle System Dynamics*, 40, pp. 351–371, 2003.

13. Zuo, L. and Nayfeh, S. A., "Minimax Optimization of Multi-Degree-of-Freedom Tuned-Mass Dampers," *Journal of Sound and Vibration* 272, pp. 893–908, 2004.

14. Varanasi, K. K. and Nayfeh, S. A., "Dynamics of Leadscrew Drives: Low-Order Modeling and Experiments," *Journal of Dynamic Systems, Measurement, and Control*, 126, pp. 388-396, 2004.

15. Nayfeh, S. A., "Damping of Flexural Vibration in the Plane of Lamination of Elastic-Viscoelastic Sandwich Beams" *Journal of Sound and Vibration* 276, pp. 689–711, 2004.

16. Abbot, R., Adhikari, R., Allen, G., Bagline, D., Cambpbell, C., Coyne, D., Daw, E., DeBra, D., Faludi, J., Fritschel, P., Ganguli, A., Giaime, J., Hammond, M., Hardham, C., Harry, G., Hua, W., Jones, L., Kern, J., Lantz, B., Lilienkamp, K., Mailand, K., Mason, K., Mittleman, R., Nayfeh, S., Ottaway, D., Phinney, J., Rankin, W., Robertson, N., Scheffler, R., Shoemaker, D. H., Wen, S., Zucker, M., and Zuo, L., "Seismic Isolation Enhancements for Initial and Advanced LIGO," *Classical and Quantum Gravity* 21, pp. 915–921, 2004.

17. Nayfeh, S. A. and Varanasi, K. K., "A Model for the Damping of Torsional Vibration of Thin-Walled Tubes With Constrained Viscoelastic Layers," *Journal of Sound and Vibration*, 278, pp. 825–846, 2004.

18. Zuo, L. and Nayfeh, S. A., "Optimization of the Individual Stiffness and Damping Parameters of Multiple-Tuned-Mass-Damper Systems," *Journal of Vibration and Acoustics*, 127, pp. 77–83, 2005.

19. Zuo, L., Slotine, J-J. S., and Nayfeh, S. A., "Model-Reaching Adaptive Control for Vibration Isolation," *IEEE Journal of Control Systems Technology*, accepted.

20. Zuo, L. and Nayfeh, S. A., "The Two-Degree-of-Freedom Tuned-Mass Damper for Suppression of Single-Mode Vibration Under Random and Harmonic Excitation," *Journal of Vibration and Acoustics*, accepted.

Proceedings of Refereed Conferences

1. Nayfeh, S. A., and Nayfeh, A. H., "The Response of Nonlinear Systems to Modulated High-Frequency Input," *Dynamics and Vibration of Time-Varying Systems and Structures, ASME 14th Biennial Conference on Mechanical Vibration and Noise*, Albuquerque, New Mexico, 1993.

2. Nayfeh, S. A., and Asada, H., "Orthogonal Sets of Design Changes for Torsional Vibration Problems," *Symposium on the Vibration of Continuous Systems, ASME 15th Biennial Conference on Vibration and Noise*, Boston, Massachusetts, 1995.

3. Scagnetti, P., Marsh, E., Slocum, A., and Nayfeh, S., "A New Method for Improving Dynamic Stiffness of Advanced Ceramic Structures," *American Society for Precision Engineering 11th Annual Meeting*, Austin, Texas, 1996.

4. Nayfeh, S. A., and Slocum, A. H., "Flexural Vibration of a Viscoelastic Sandwich Beam in its Plane of Lamination," *Symposium on the Vibration of Continuous Systems, ASME 16th Biennial Conference on Vibration and Noise*, Sacramento, California, 1997.

5. Nayfeh, S. A., and Slocum, A. H., "Enhancing Ballscrew Axial Dynamics," *American Society for Precision Engineering 13th Annual Meeting*, St. Louis, Missouri, 1998.

6. Devitt, D., Nayfeh, S. A., and Varanasi, K. K., "Dynamic Stiffness of Porous Air bearings and Force-Balanced Bearing," *American Society for Precision Engineering 14th Annual Meeting*, Monterey, California, 1999.

7. Nayfeh, S. A., Varanasi, K., "Design of Leadscrew Drives for Dynamic Performance," *American Society for Precision Engineering 16th Annual Conference*, Crystal City, Virginia, 2001.

8. Nayfeh, S. A., "Constrained-Layer Damping of Torsional Vibration of Thin-Walled Tubes," *ASME 18th Biennial Conference on Vibration and Noise*, Pittsburgh, Pennsylvania, 2001.

9. Zuo, L. and Nayfeh, S. A., "Design of Multi-Degree-of-Freedom Tuned-Mass Dampers: a Minimax Approach," *43rd AIAA Structures, Structural Dynamics, and Materials Conference*, Denver, Colorado, 2002.

10. Zuo, L. and Nayfeh, S. A., "Design of Passive Mechanical Systems via Decentralized Control Techniques," *43rd AIAA Structures, Structural Dynamics, and Materials Conference*, Denver, Colorado, 2002.

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12. Al–Nahwi, A. A., Pauduano, J. D., and Nayfeh, S. A., "Aerodynamic-Rotordynamic Interaction in Axial Compression Systems—Part II: Impact on Overall System Stability," *ASME/IGTI Turbo Expo 2002*, Amsterdam, The Netherlands, 2002.

13. Zuo, L. and Nayfeh, S. A., "Decentralized H2 Optimal Control with Regional Pole Constraints," *American Control Conference 2003*, Denver, Colorado, 2003.

14. Varanasi, K. K., and Nayfeh, S. A., "Damping of Flexural Vibration by Low-Density Foam and Granular Materials," *ASME Design Engineering Technical Conference 2003*, Chicago, Illinois, 2003.

15. Zuo, L., and Nayfeh, S. A., "The Multi-Degree-of-Freedom Tuned-Mass Damper for Suppression of Single-Mode Vibration under Random and Harmonic Excitation," *ASME Design Engineering Technical Conference 2003*, Chicago, Illinois, 2003.

16. Verdirame, J. M. and Nayfeh, S. A., "Design of Multi-Degree-of-Freedom Tuned-Mass Dampers using Perturbation Techniques," *44th AIAA Structures, Structural Dynamics, and Materials Conference*, Norfolk, Virginia, 2003.

17. Zuo, L. and Nayfeh, S. A., "Active Vibration Isolation Using a Post-Buckled Spring," *ASPE Spring Topical Meeting: Control of Precision Systems*, Boston, Massachusetts, 2004.

18. Zuo, L. and Nayfeh, S. A., "Damping of Vibration in Belt-Driven Motion Systems Using a Layer of Low-Density Foam," *ASPE Spring Topical Meeting: Control of Precision Systems*, Boston, Massachusetts, 2004.

19. Zuo, L., Slotine, J-J. S., and Nayfeh, S. A., "Experimental Study of a Novel Adaptive Controller for Active Vibration Isolation,", *2004 American Control Conference*, Boston, Massachusetts, 2004.

20. Varanasi, K. K. and Nayfeh, S. A., "Vibration Damping Using Low-Wave-Speed Media: Complex Wavenumber and Energy Approximations," *ASME Design Engineering Technical Conference 2005*, Long Beach, California, 2005.

21. Verdirame, J. M. and Nayfeh, S. A., "Vibration Damping in Cylindrical Shells filled with Low-Density, Low-Wave-Speed Media," *ASME Design Engineering Technical Conference 2005*, Long Beach, California, 2005.

22. Zuo, L. an Nayfeh, S. A., "Adaptive Feedforward Control with Saturation Nonlinearity," *ASME Design Engineering Technical Conference 2005*, Long Beach, California, 2005.

Patents and Patent Applications Pending

1. Maue, H. W., Krupp, E. J., Maass., M N., Sims, J. R., Nayfeh, S. A., Raade, J. W., Cai, A. W., Faiz, J. S., Montoya, M., Rios, E., Tribin, P., Blanco, E., "Single motor module for a vehicle seat," 6,626,064, 2003.

2. Bryn, L., Nayfeh, S. A., Islam, M., Lowery Jr., W. L., and Harries H. D., "Loom and Method of Weaving Three-Dimensional Woven Forms with Integral Bias Fibers," Published US Application 20040168738, 2004.

3. Varanasi, K. K. and Nayfeh, S. A., "Damping of Structural Vibration Using Low-Wave-Speed Materials," US Application (10/821344), 2004.

4. Nayfeh, S. A., Rohrs, J., Diaz, M., Rifai, O., Warman, E., "Bias Weaving Loom," US Application (60/579474), 2004.

5. Rohrs, J. and Nayfeh, S. A., "Modular Weaving for Small-Batch Production," US Application, 2005.

Other Major Publications

1. Nayfeh, A. H., Nayfeh, S. A., Anderson, T. J., and Balachandran, B., "Transfer of Energy from High-Frequency to Low-Frequency Modes," *Nonlinearity and Chaos in Engineering Systems*, edited by Thomson, J. M. T. and Bishop, S. R., Wiley Interscience, 1994.

2. Nayfeh, A. H., Nayfeh, S. A., and Pakdemirli, M., "On the Discretization of Weakly Nonlinear Spatially Continuous Systems," *Nonlinear Dynamics and Stochastic Mechanics*, edited by Klienmann, W. and Namachchivaya, N. S., CRC Press, 1995.

3. Vallance, R., Kiani, S., and Nayfeh, S., "Open Design of Manufacturing Equipment," *Proceedings of CIRP First International Conference on Agile, Reconfigurable Manufacturing*, Ann Arbor, Michigan, 2001.

4. Verdirame, J. M., Nayfeh, S. A., and Zuo, L., "Design of Multi-Degree-of-Freedom Tuned-Mass-Dampers," *SPIE's 9th Annual International Symposium on Smart Structures and Materials*, San Diego, California, 2002.

5. Nayfeh, S. A., Verdirame, J. M., and Varanasi, K. K., "Damping of Flexural Vibration by Coupling to Low-Density Granular Materials," *SPIE's 9th Annual International Symposium on Smart Structures and Materials*, San Diego, California, 2002.

6. Trumper, D. L., Nayfeh, S. A., Lilienkamp, K. A., "Projects for Teaching Mechatronics at MIT," *Proceedings of the Eighth International Conference on Mechatronics*, Enschede, The Netherlands, 2002.

7. Slocum, A. H., Basaran, M., Cortesi, R., and Nayfeh, S. A., "Get a Preload of This: Actuator and Bearing Technology is Changing How Grinding Machines Move," *American Machinist*, December, 2002.

8. Nayfeh, S. A., Varanasi, K. K., and Verdirame, J. M., "Vibration Damping by Low-Sound-Speed Material Layers" *SPIE's 10th Annual International Symposium on Smart Structures and Materials*, San Diego, California, 2003.

9. Zuo, L. and Nayfeh, S. A., "Optimal Design of MDOF and Multiple SDOF Tuned-Mass Dampers for Wide-Band Vibration Suppression," *SPIE's 10th Annual International Symposium on Smart Structures and Materials*, San Diego, California, 2003.

10. Varanasi, K. K. and Nayfeh, S. A., "Damping in Belt-Driven Servomechanisms Using Low-Density, Low-Wave-Speed Materials," *SPIE's 11th Annual International Symposium on Smart Structures and Materials*, San Diego, California, 2004.

11. Zuo, L., and Nayfeh, S. A., "An Integral Sliding Control for Robust Vibration Isolation and its Implementation," *SPIE's 11th Annual International Symposium on Smart Structures and Materials*, San Diego, California, 2004.

12. Varnasi, K. K. and Nayfeh, S. A., "Damping of Drive Resonances in Belt-Driven Motion Systems Using Low-Wave-Speed Media," *The Seventh International Conference on Motion and Vibration Control*, St. Louis, Missouri, 2004.

13. Zuo, L. and Nayfeh, S. A., "Active-Passive Vibration Isolation and Position Control Using a Post-Buckled Spring," *The Seventh International Conference on Motion and Vibration Control*, St. Louis, Misouri, 2004.

14. Zuo, L. and Nayfeh, S. A., "Modified LMS Feed-Forward Control for Vibration Isolation with Actuator Limits," *SPIE's 12th Annual International Symposium on Smart Structures and Materials*, San Diego, California, 2005.

15. Verdirame, J. M. and Nayfeh, S. A., "Vibration Damping in Cylindrical Shells Filled With Low-Density, Low-Wave-Speed Media," *SPIE's 12th Annual International Symposium on Smart Structures and Materials*, San Diego, California, 2005.

Selected Invited Lectures

1. "Some New Twists on the Dynamic Vibration Absorber," October 2003, Department of Mechanical Engineering, Tufts University, Medford, Massachusetts
2. "Vibration Suppression by Dynamic Interaction with Low-Density, Low-Wave-Speed Media," October 2003, Center for Acoustics and Vibration, The Pennsylvania State University, College Station, Pennsylvania.
3. "Some New Approaches to Vibration Suppression in Precision Machines," October 2003, Department of Mechanical Engineering, University of Maryland, College Park, Maryland.
4. "Some New Approaches to Vibration Suppression in Precision Machines," October 2003, National Institute of Standards and Technology, Gaithersburg, Maryland.
5. "Some New Twists on the Dynamic Vibration Absorber," October 2003, Cambridge University Mechanics Colloquium, Cambridge, England.
6. "Bias-Woven Structures," March 2004, Mechanics Seminar, MIT Department of Mechanical Engineering, Cambridge, Massachusetts.
7. "Vibration Damping for Sound and Vibration Reduction," July 2004, Ford Motor Company Advanced Technology Center, Dearborn, Michigan.
8. "Vibration Damping in Precision Machines," September 2004, Philips Research Center, Eindhoven, The Netherlands.
9. "Three-Dimensional Bias Weaving," February 2005, Technical University of Eindhoven, The Netherlands.

Doctoral Theses Supervised

1. Varanasi, Kripa, "Vibration Damping Using Low-Wave-Speed Media with Application to Precision Machines," February 2004.
2. Dever, Christopher, "Parameterized Maneuvers for Autonomous Vehicles," August 2004 (reader).
3. Zuo, Lei, "Element and System Design for Active and Passive Vibration Isolation," October 2004.
4. Wilson, Andrew, "In-Situ Inspection of Optical Fiber Connections," expected August 2005.
5. Verdirame, Justin, "Integral Damping of Vehicle Propellor Shaft," expected May 2006.

6. Rohrs, Jonathan, "Short-Warp Weaving," expected May 2006.

Master's Theses Supervised

1. Schiller, David, "Investigation of Methods of Compensating for Setting Problems of Tapered Roller Bearings in Dimensionally Unstable Bearing Housings," May 1999.
2. Athanasopoulus, Andreas, "Design of Damped Toolholders for Increased Cutting Performance," May 2000.
3. Morfino, Paolo, "Damping of Torsional Vibration by Segmented Constrained-Layer Dampers," Dec 2000, visiting student from Turino.
4. Valdivia, Pablo, "Design, Analysis and Control of an Autonomous Conveyance Module for Well Exploration," May 2001.
5. Wilson, Andrew "Design of an Automated Cutting Head for an On-Car Brake Lathe," May 2001.
6. Varanasi, Kripa, "On the Design of a Precision Machine for Closed-Loop Performance," Jan 2002.
7. Zuo, Lei, "Decentralized Control Techniques and Their Application to the Design of Passive Mechanical Systems," Jan 2002.
8. Farzaneh, Nader, "Factors Affecting Galling Failures in Heavily Loaded Bushings," May 2002.
9. Radighieri, Greg, "Design of a Tester to Study Galling Failures in Heavily Loaded Bushings," May 2002.
10. Verdirame, Justin, "Design of Multi-Degree-of-Freedom Tuned-Mass Dampers Based on Perturbation Techniques," May 2002.
11. Mariappan, Dhanushkodi, "Dynamics of Belt-Driven Servomechanisms: Theory and Experiment," May 2003.
12. Diaz, Mauricio, "Design of a Bias-Weaving Machine: Bias Thread Shifting," September 2003.
13. Rohrs, Jonathan, "Design of a Bias-Weaving Machine: Thread Manipulation and Other Topics," September 2003.
14. Warmann, Emily, "Design of a Bias-Weaving Machine: Fill Insertion and Beat-Up," October 2003.

15. Kelly, Darcy, "Design and Qualification of an Absolute Thickness Measurement Machine," May 2004.

16. Akhampon, Sappinandana, "Control of a Bias-Weaving Machine," January 2004.

Bachelor's Theses Supervised

1. Banks, Perry, "Linear Drive With High Stiffness and Low Inertia," May 1999.

2. Golaski, Edmund, "A Self-Adjusting Mechanical Transmission for Low-Bandwidth Applications," May 1999.

3. Dyer, Kyrilian, G., "Design of a Mechanically Isolated Electronic Hardware Mounting System for a Small Autonomous Rotorcraft," May 2000.

4. Raade, Justin, "Design of a Multiplexing Gearbox and Zero-Backlash Flexure Clutch for Application in Automobile Seats," May 2001.

5. Redman, Debra, "Constrained-Layer Damping for Vibration Control in Torsion and Bending," May 2001.

6. Massery, Luke, "Design of an Apparatus for Visualization of Taylor–Couette Flows," May 2002.

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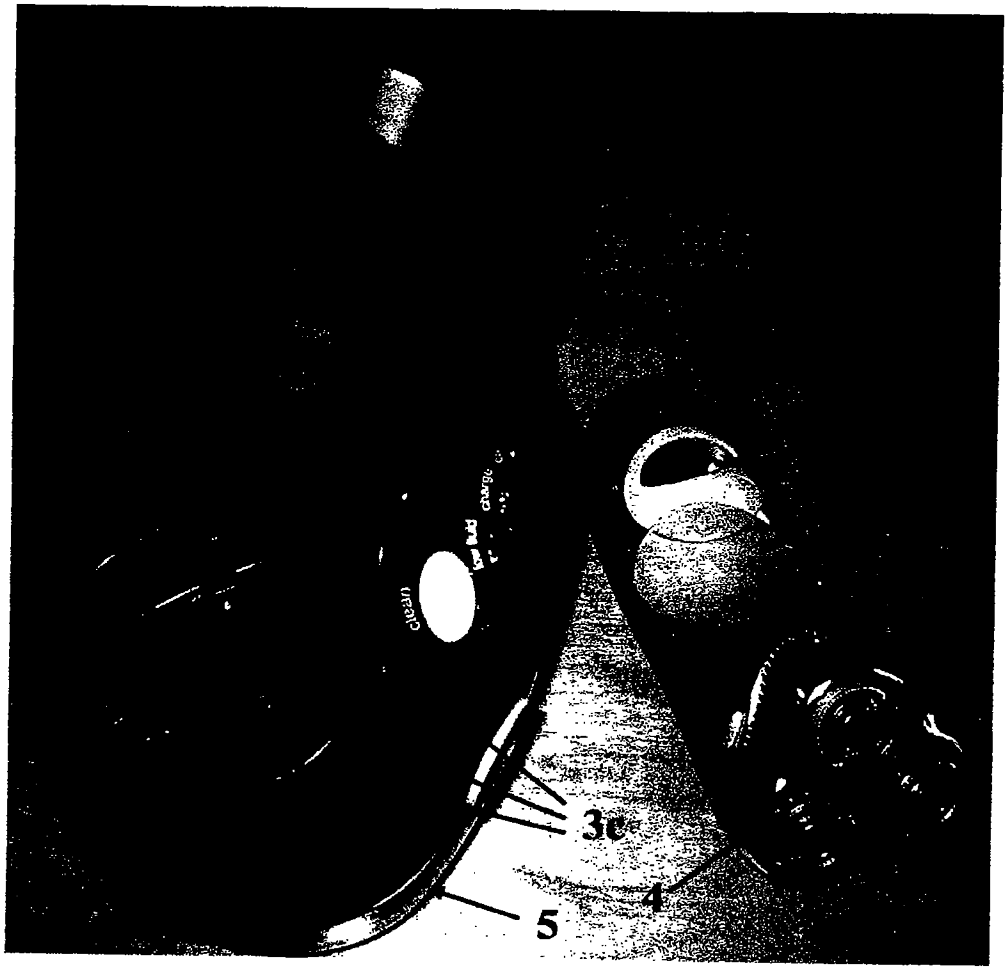

Figure 1a: Photograph of the R-9500 shaving system. The razor 1 is removed from the housing 2 of the cleaning system.

Figure 1b: Photograph of the R-9500 cleaning system. The housing 2 of the cleaning system is separated from the container 5 and filter 12.

Figure 1c: Photograph of the R-9500 cleaning system with part of its housing 2 as well as the cover of the impeller 8 removed.

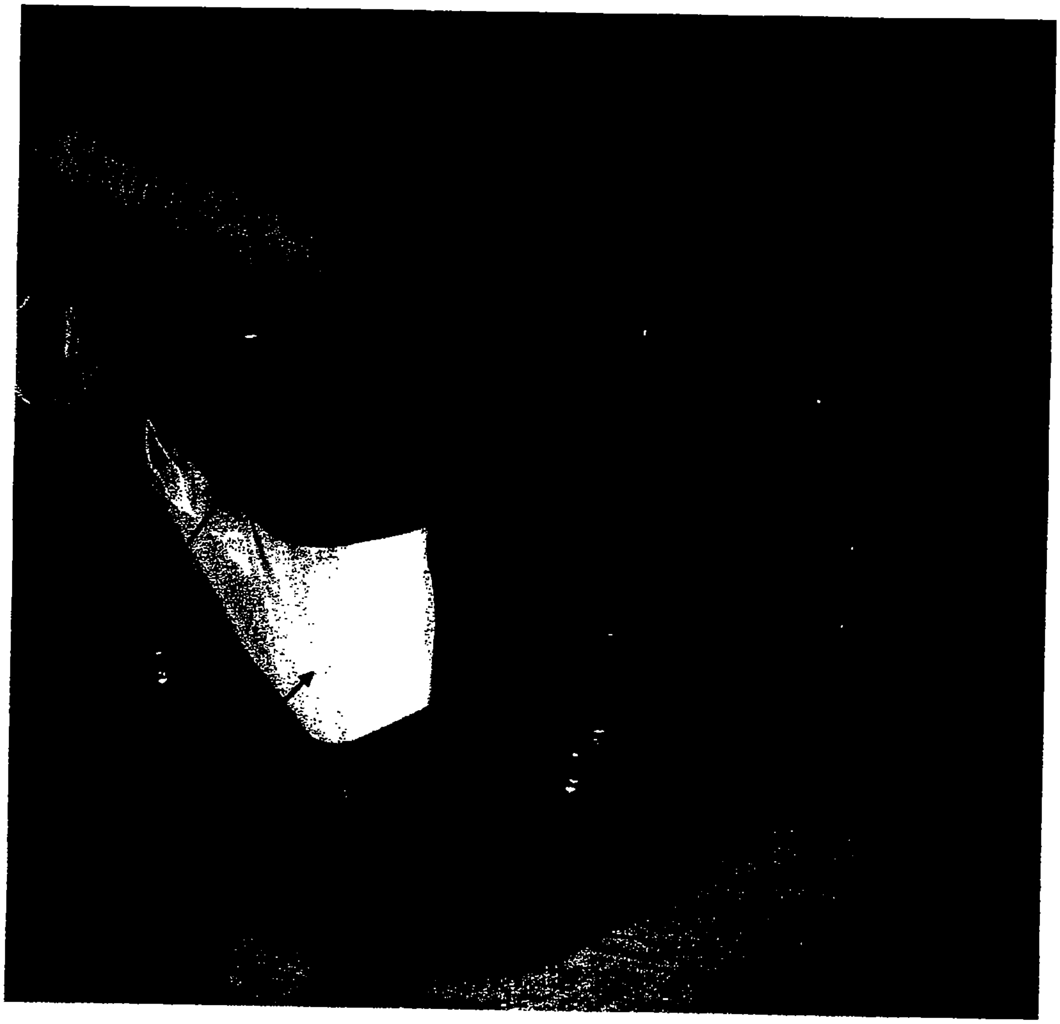

Figure 1d: Photograph of the container 5 of the R-9500 cleaning system with the filter 12 partially removed. The containers 5 and filters 12 of the MS-5500 and WDF-7000CS systems are interchangeable with those of the R-9500 system.

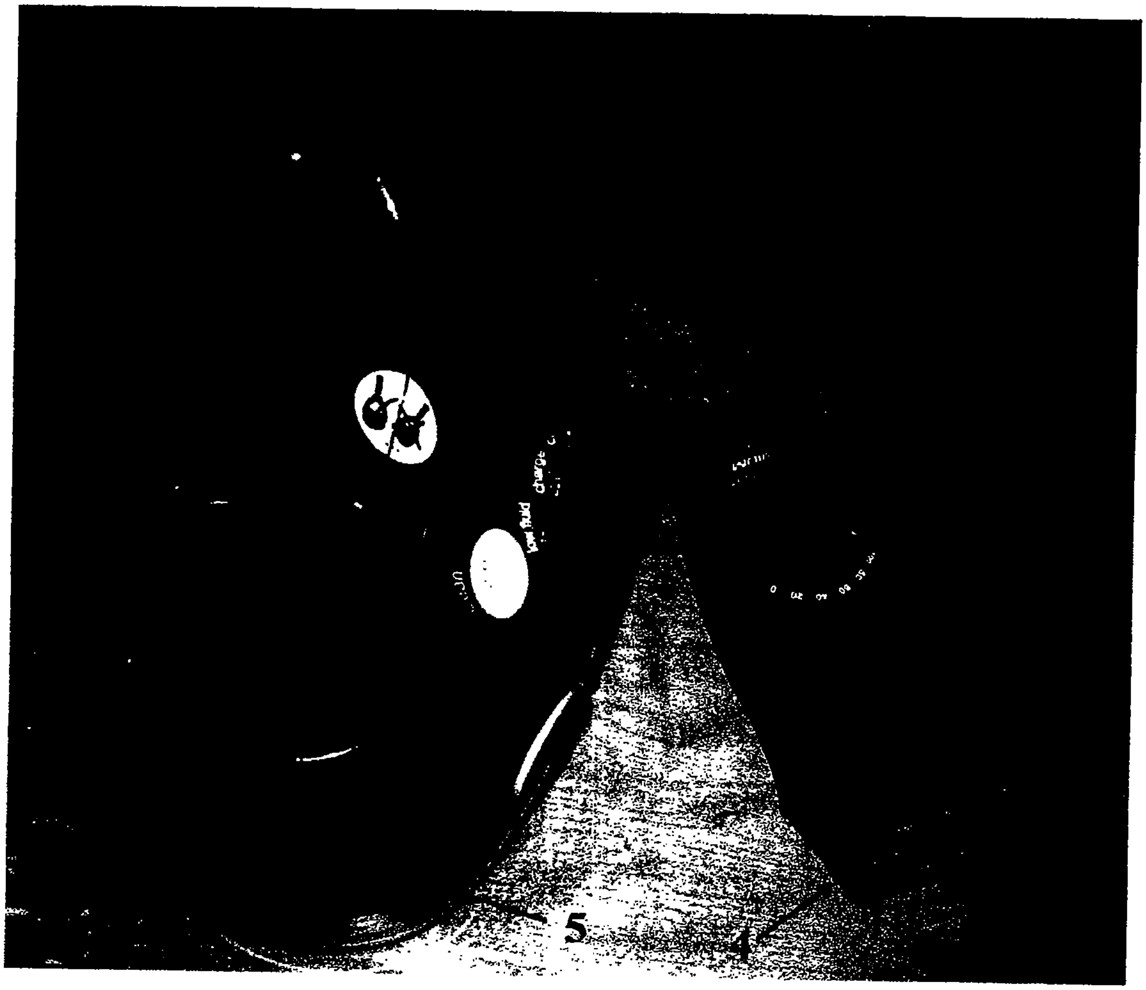

Figure 2a: Photograph of the MS-5500 shaving system. The razor 1 is removed from the housing 2 of the cleaning system.

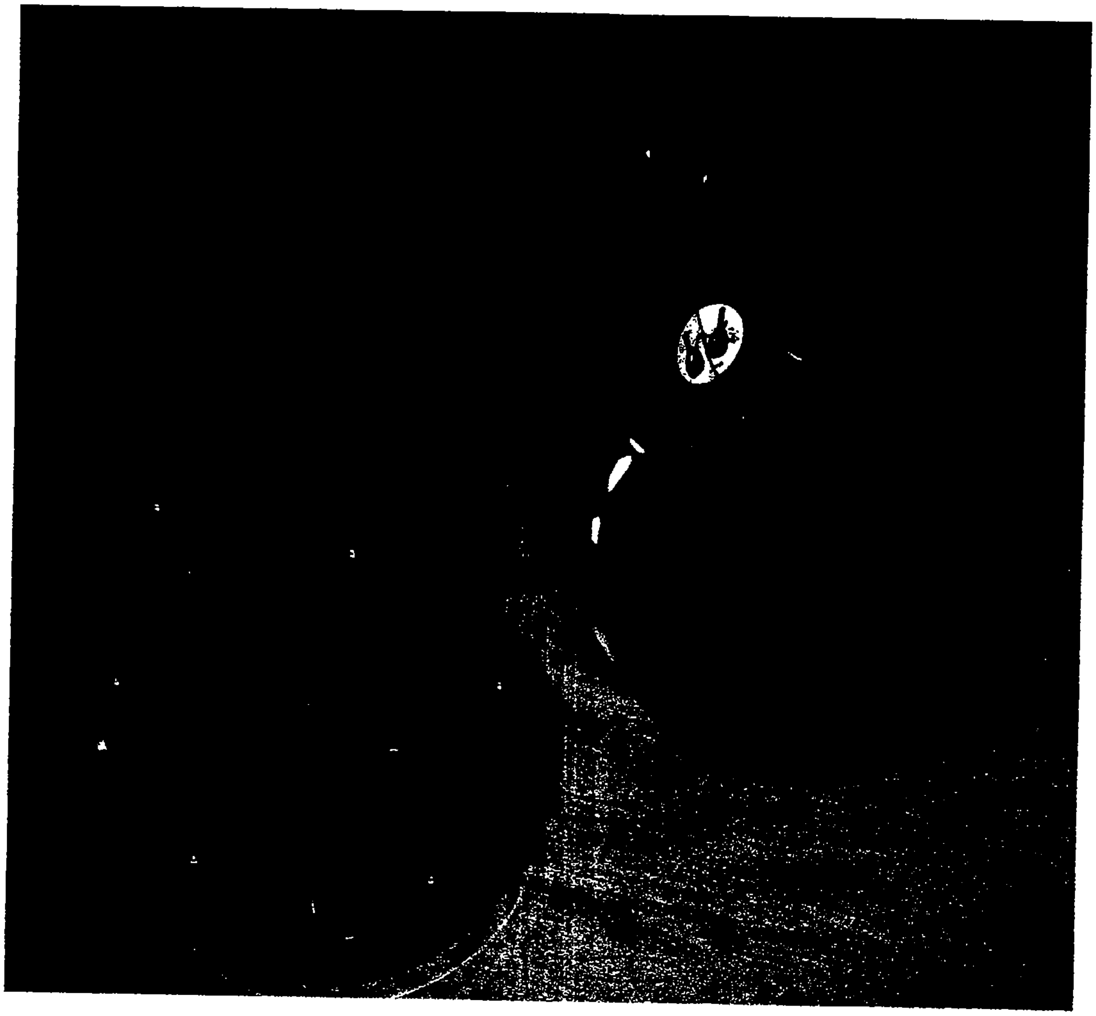

Figure 2b: Photograph of the MS-5500 cleaning system. The housing 2 of the cleaning system is separated from the container 5 and filter 12.

Figure 2c: Photograph of the R-9500 cleaning system with part of its housing 2 as well as the cover of the impeller 8 removed.

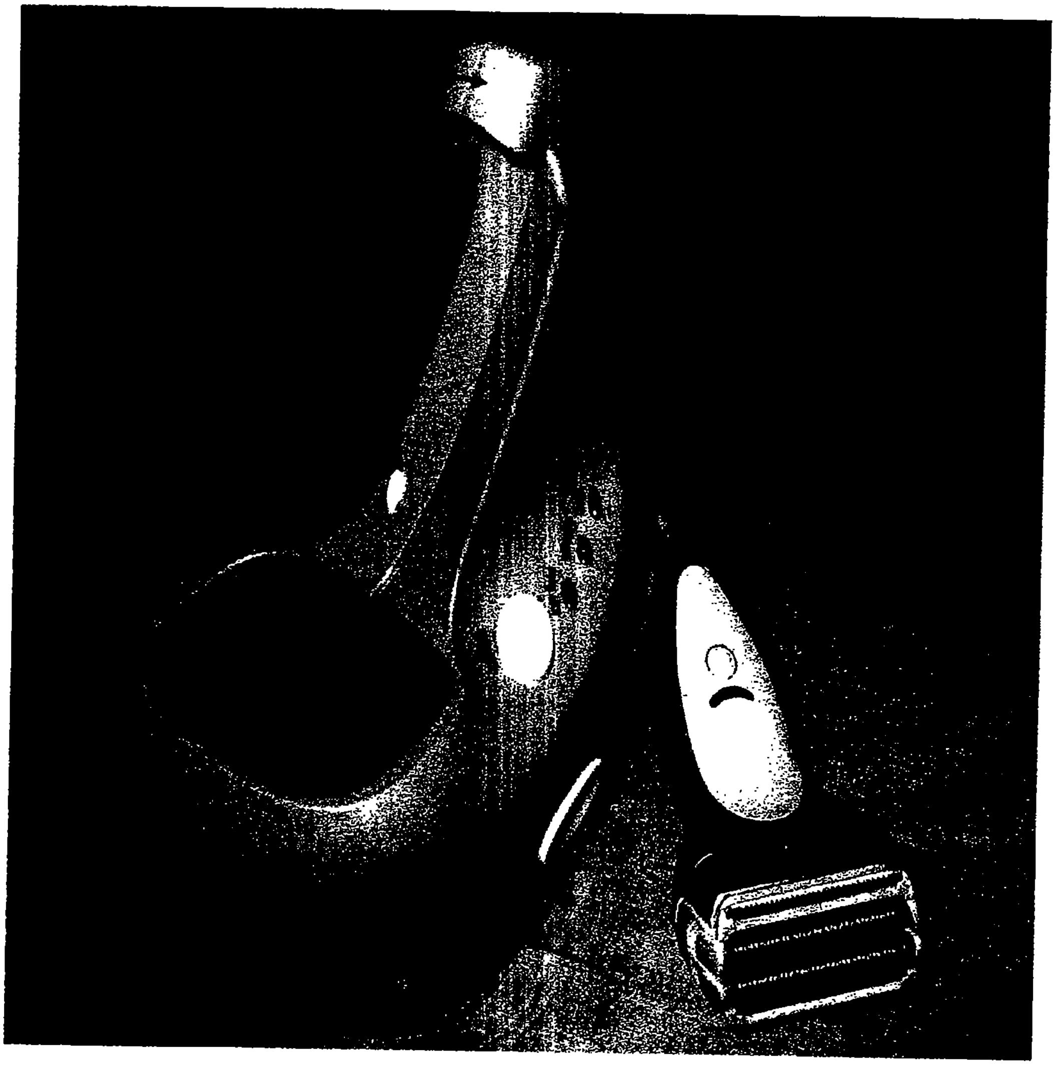

Figure 3a: Photograph of the WDF-7000CS shaving system. The razor 1 is removed from the housing 2 of the cleaning system.

Figure 3b: Photograph of the WDF-7000CS cleaning system. The housing 2 of the cleaning system is separated from the container 5 and filter 12.

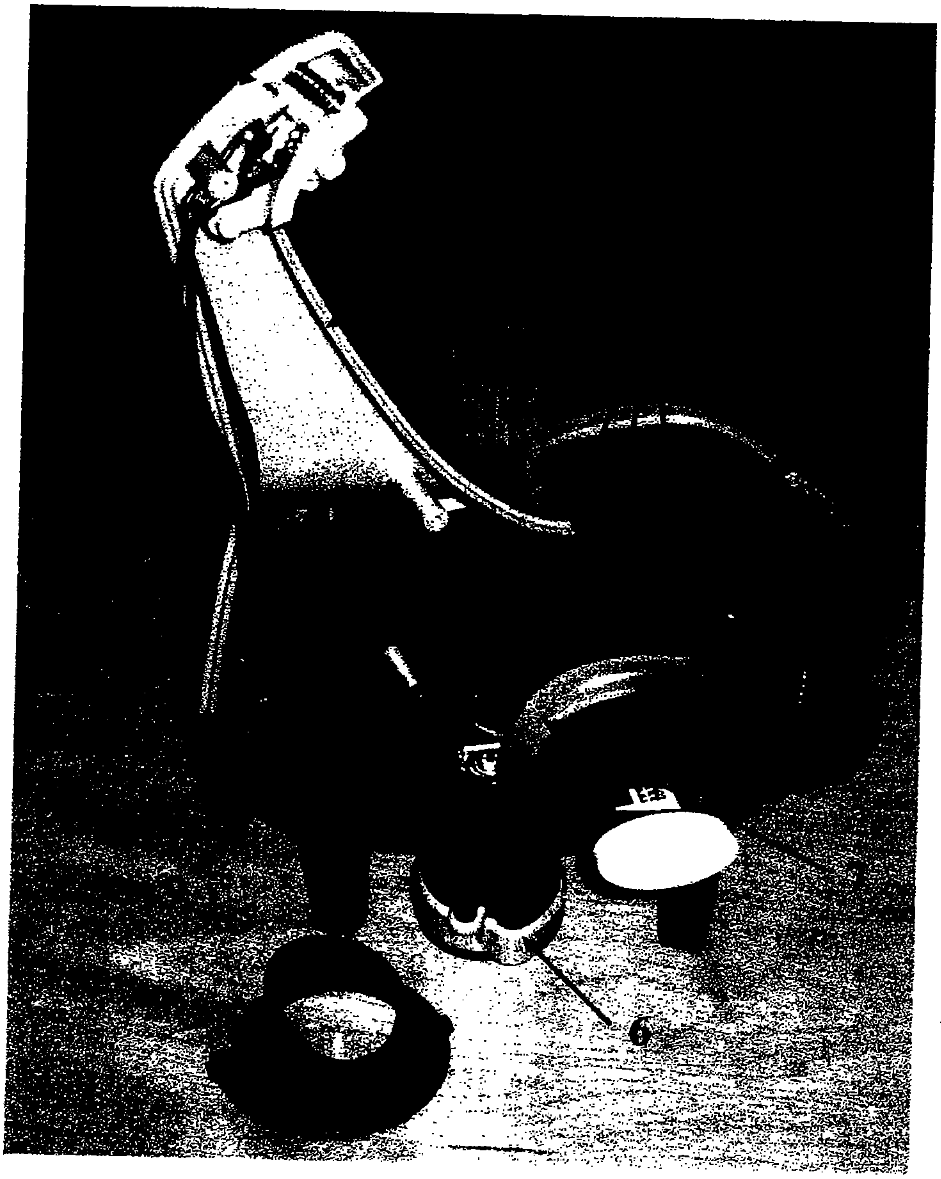

Figure 3c: Photograph of the WDF-7000CS cleaning system with part of its housing 2 as well as the cover of the impeller 8 removed.